An Iris Recognition Algorithm Using Phase-Based Image Matching

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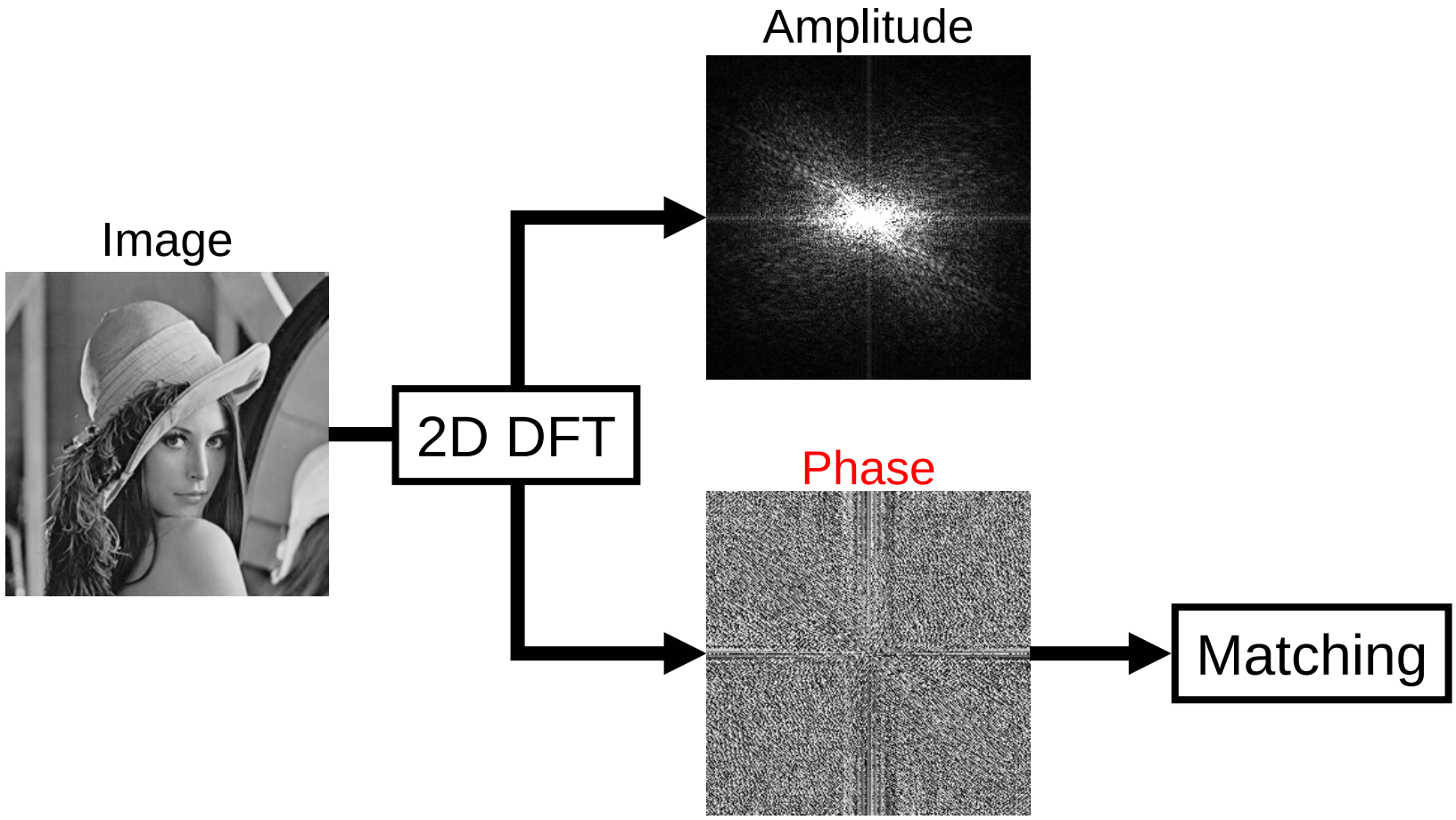
Kazuyuki MIYAZAWA[1], Koichi ITO[1], Takafumi AOKI[1],
Koji KOBAYASHI[2] and Hiroshi NAKAJIMA[2]

[1] Tohoku University, Japan

[2] Yamatake Corporation, Japan

What Is Phase-Based Image Matching?

- Using phase components in 2D Discrete Fourier Transforms (DFTs) of given images.



Biometrics with Phase-Based Image Matching

- Application to image registration

  C. D. Kuglin et al., "The phase correlation image alignment method," Proc. Int. Conf. Cybernetics and Society, 1975.

- Application to biometrics (fingerprint)

  H. Nakajima et al., "Pattern collation apparatus based on spatial frequency characteristics," US Patent, 1995.

- Commercial fingerprint verification unit (1998)

- Other successful applications (biometrics)
  - Iris recognition
  - 3D face recognition
  - Palmprint recognition

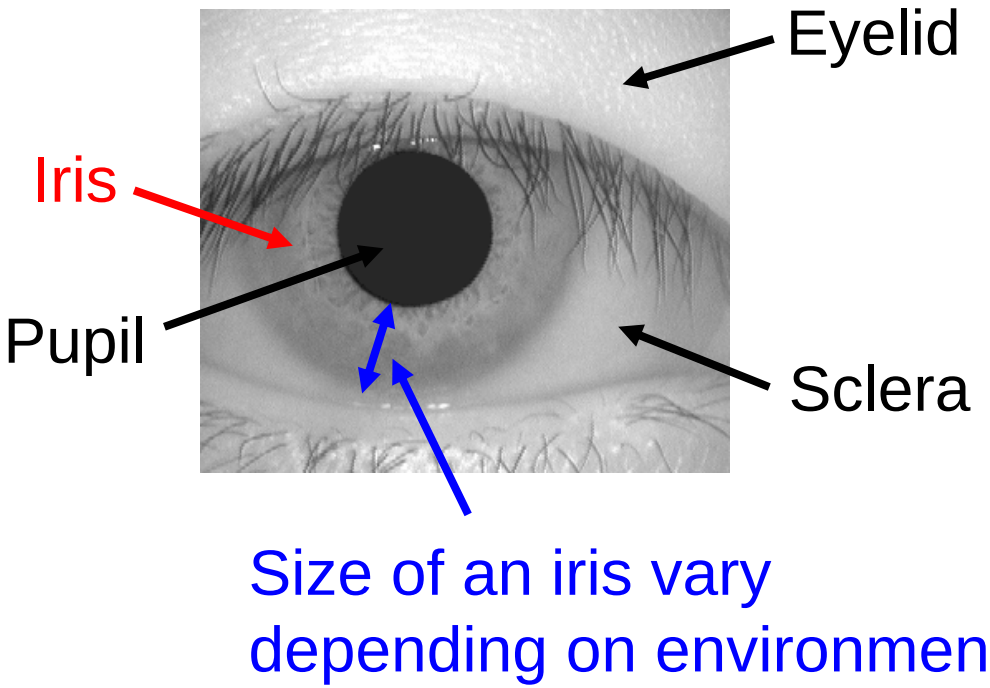
FriendTouch

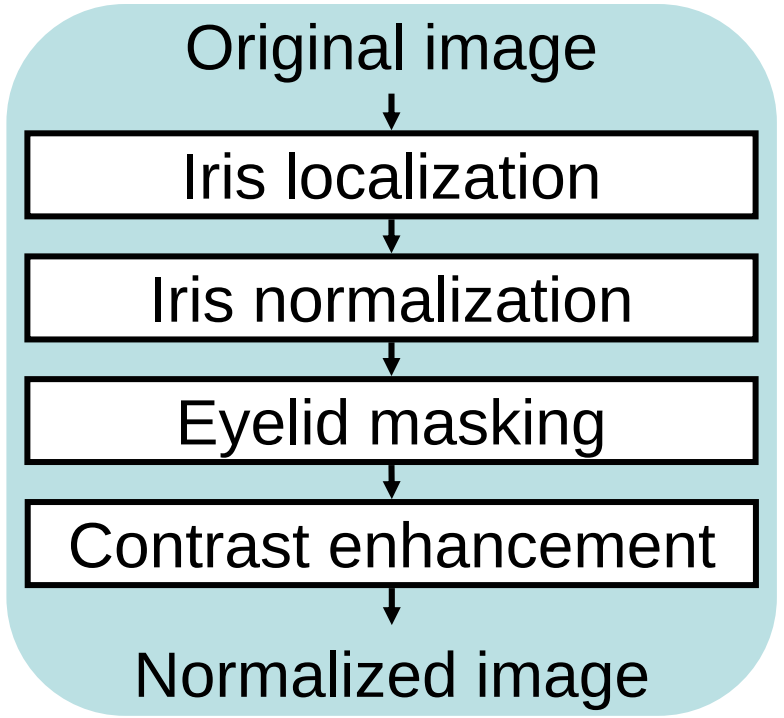
ASIC for phase-based image matching

Outline

- Background
- Preprocessing stage
- Matching stage
- Experimental results of ICE 2005
- Conclusion and future plans

Preprocessing Stage

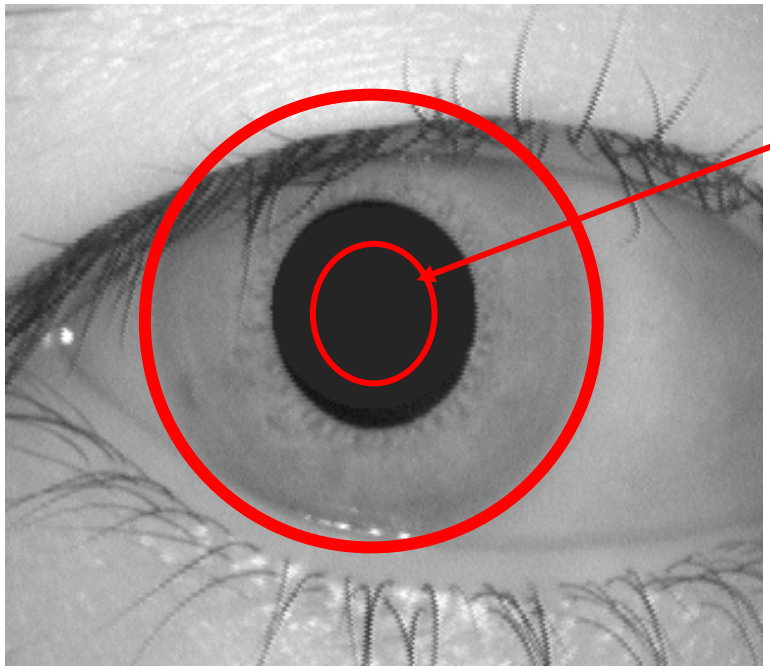




- Remove the parts that are not necessary for recognition.
- Normalize iris region to reduce the influence of environmental factors.

Iris Localization

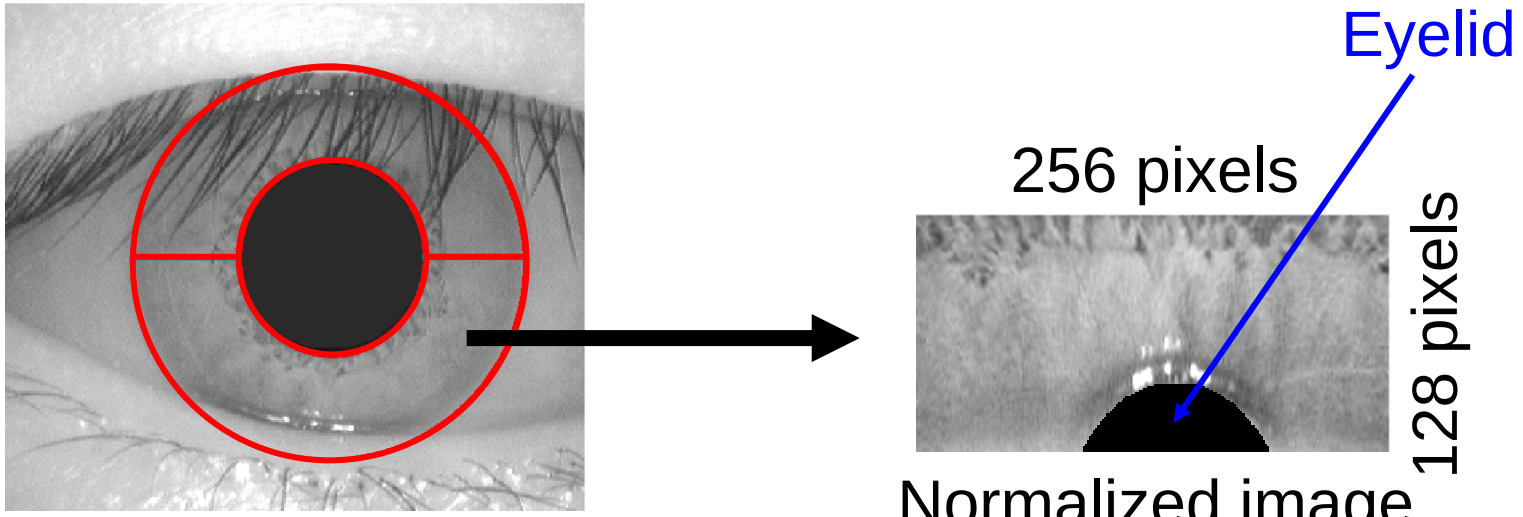
- Based on Dr. Daugman's approach



1. Calculate contour integral along the ellipse.
2. Compute integral derivative in the axis direction of the ellipse with increasing the lengths of axes.

- Detect the inner boundary by finding the ellipse which maximizes the derivative.

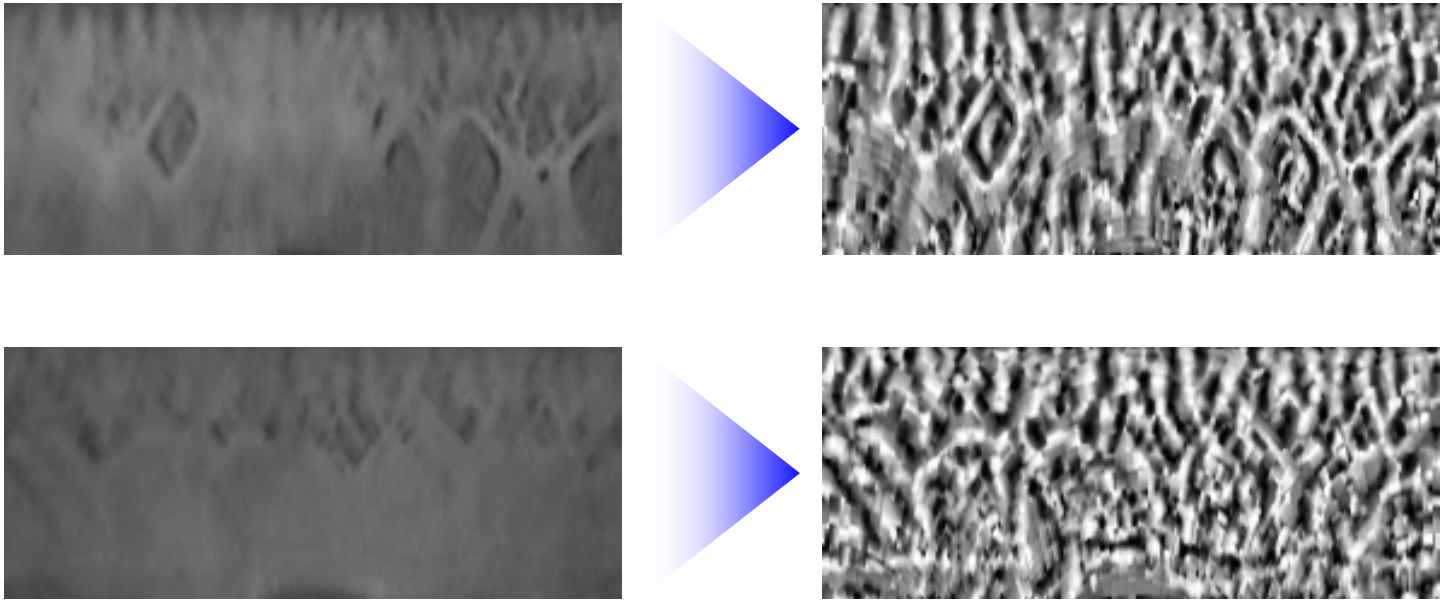
Iris Normalization



- Use only the lower half of the iris region.
- Eyelid is not necessary for recognition.
- Using the same method for detecting the inner boundary, detect the eyelid boundary.

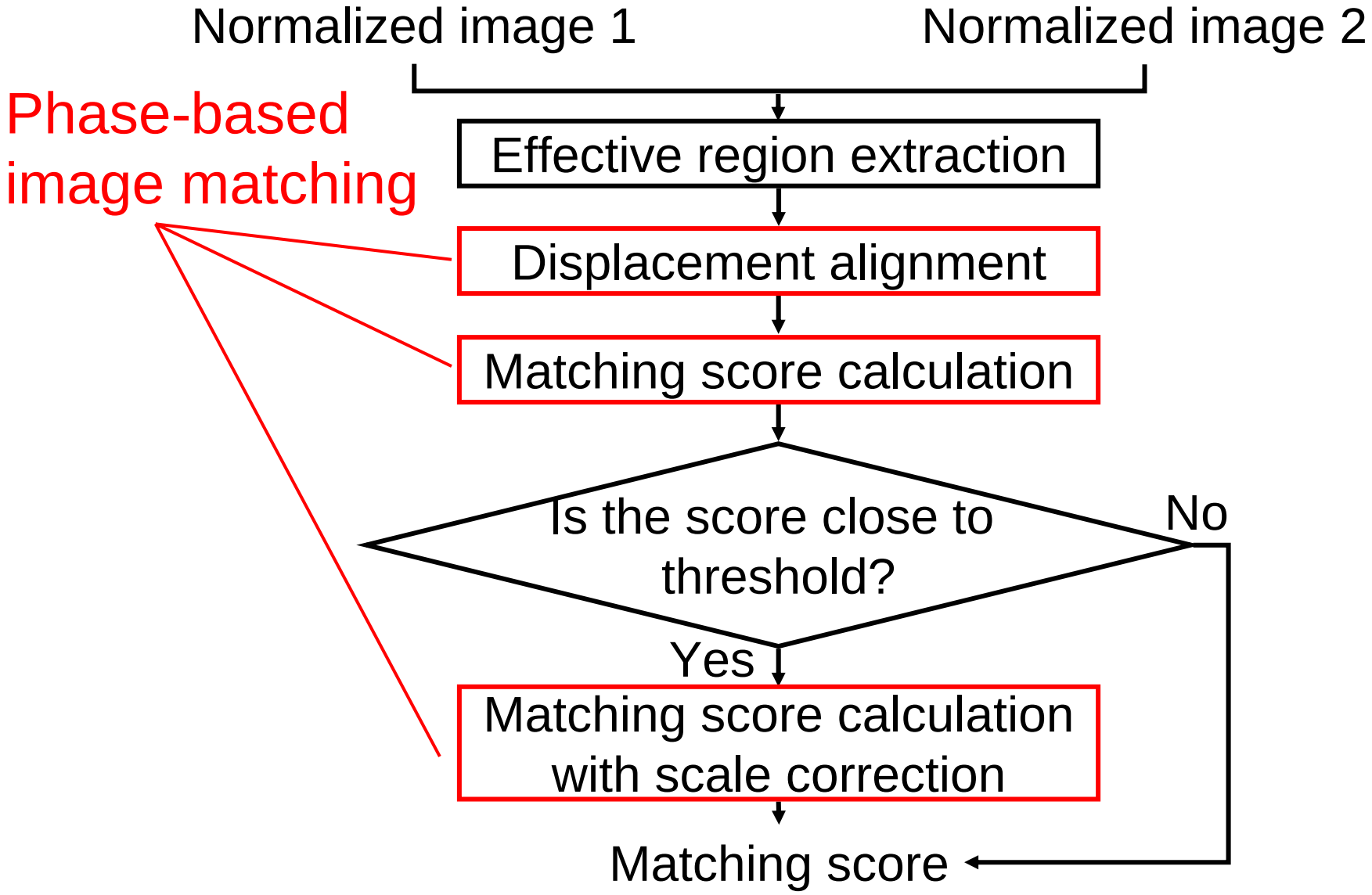
Contrast Enhancement

Normalized image | Enhanced image



- In some databases, the normalized iris image has low contrast.
- Improve the contrast by using local histogram equalization.

Matching Stage



Phase-Based Image Matching

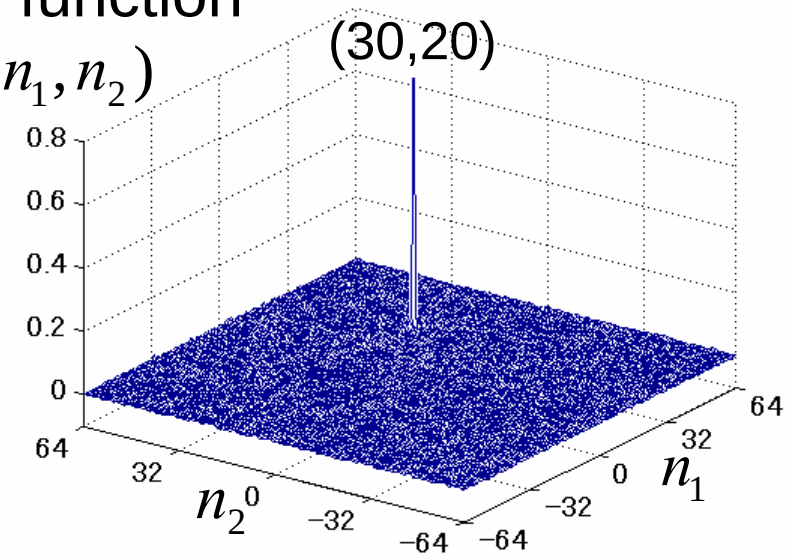
- Phase-Only Correlation (POC) function

Image 1

Image 2

POC function

$r(n_1, n_2)$



POC function has a sharp peak like a delta function.

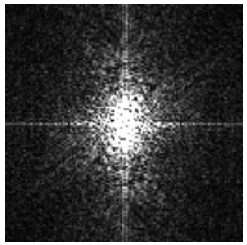
Location of the correlation peak: Translational image shifts

Height of the correlation peak: Similarity of images

Basic Computation Flow for POC Function

Spatial Domain

Frequency Domain



Input images

$f(n_1, n_2)$

$g(n_1, n_2)$

2D DFT

$$F(k_1,k_2) = A_F(k_1,k_2)e^{j\theta_F(k_1,k_2)}$$

$$G(k_1,k_2) = A_G(k_1,k_2)e^{j\theta_G(k_1,k_2)}$$

Amplitude Phase

POC function

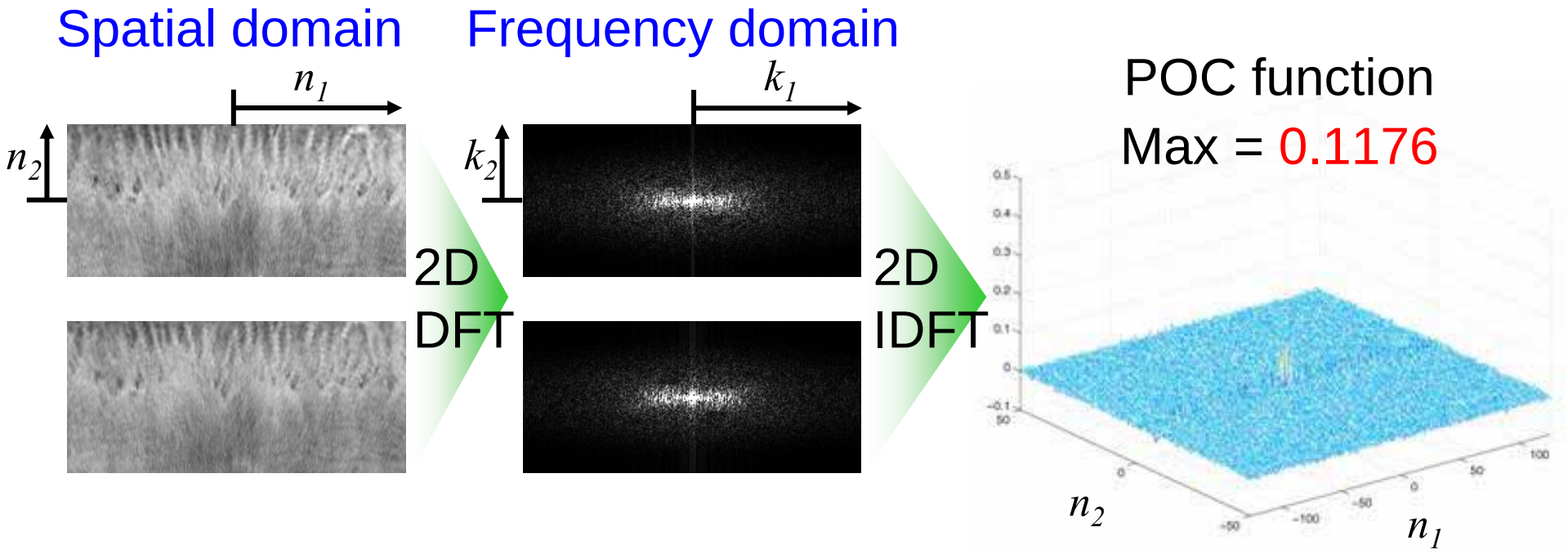
$r(n_1, n_2)$

2D IDFT

Cross-phase spectrum

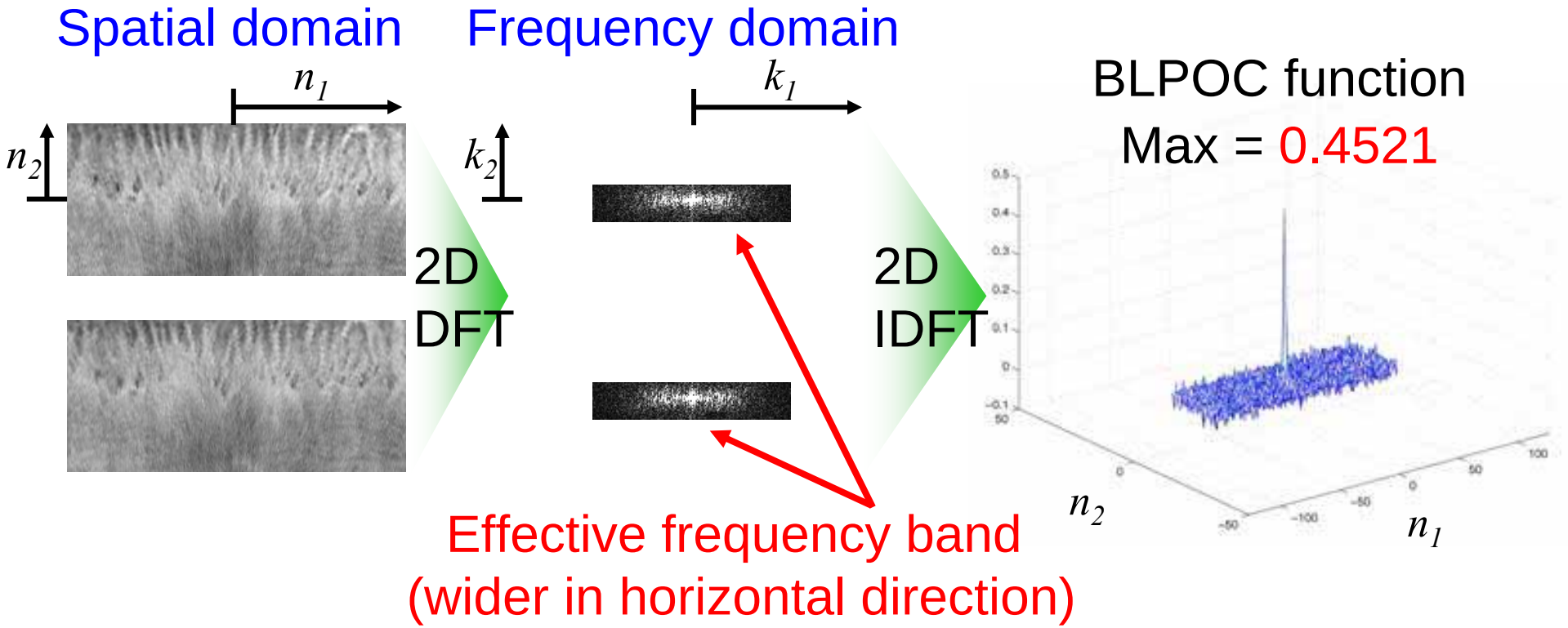
$$R(k_1,k_2) = \frac{F(k_1,k_2)}{|F(k_1,k_2)|} \cdot \frac{\overline{G(k_1,k_2)}}{|\overline{G(k_1,k_2)}|} = e^{j\{\theta_F(k_1,k_2) - \theta_G(k_1,k_2)\}}$$

Degradation of Accuracy



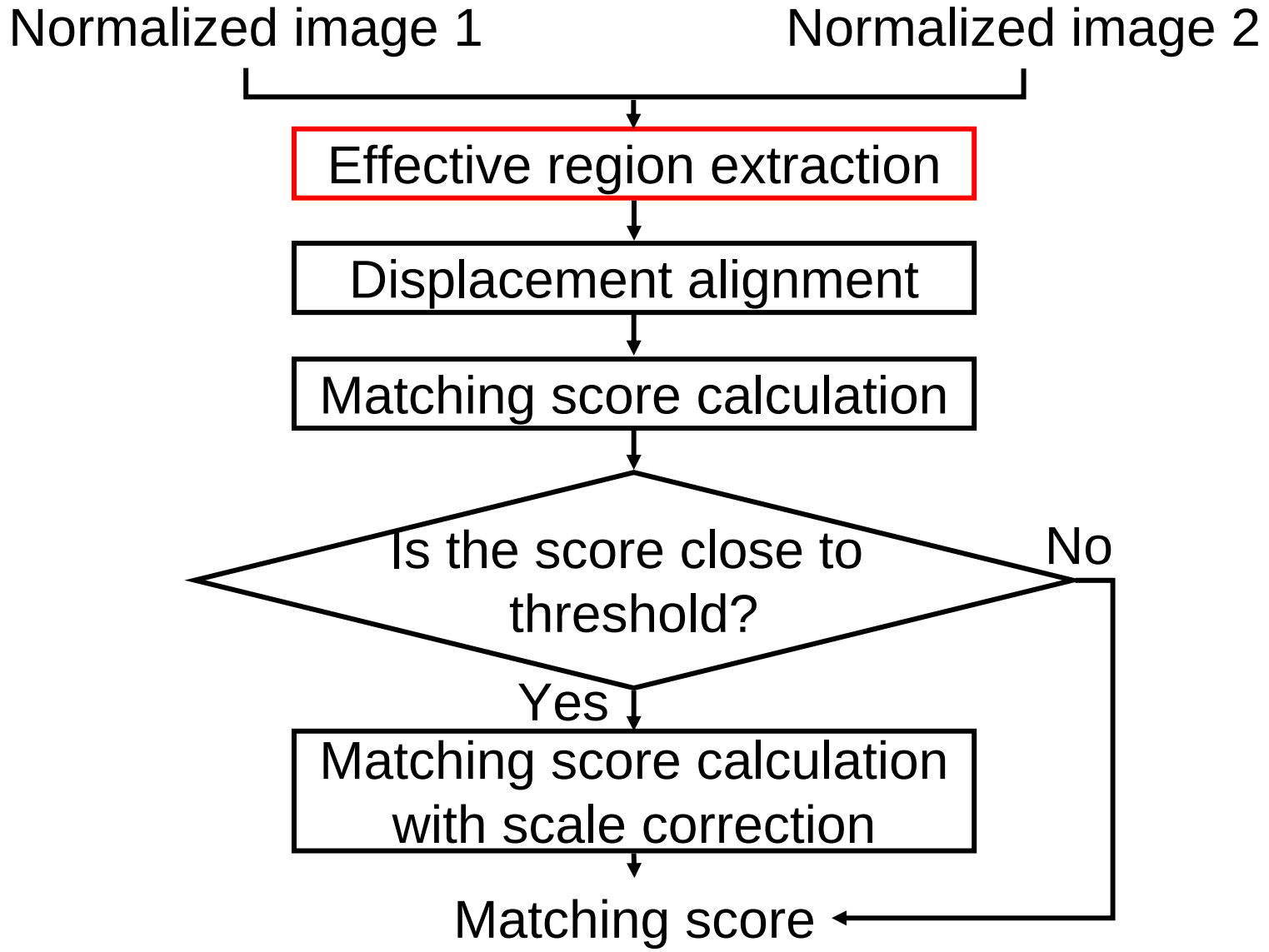
- 2D DFT of a normalized iris image has unreliable phase components in high frequency domain.
- The height of the correlation peak is reduced.

Band-Limited POC (BLPOC) Function

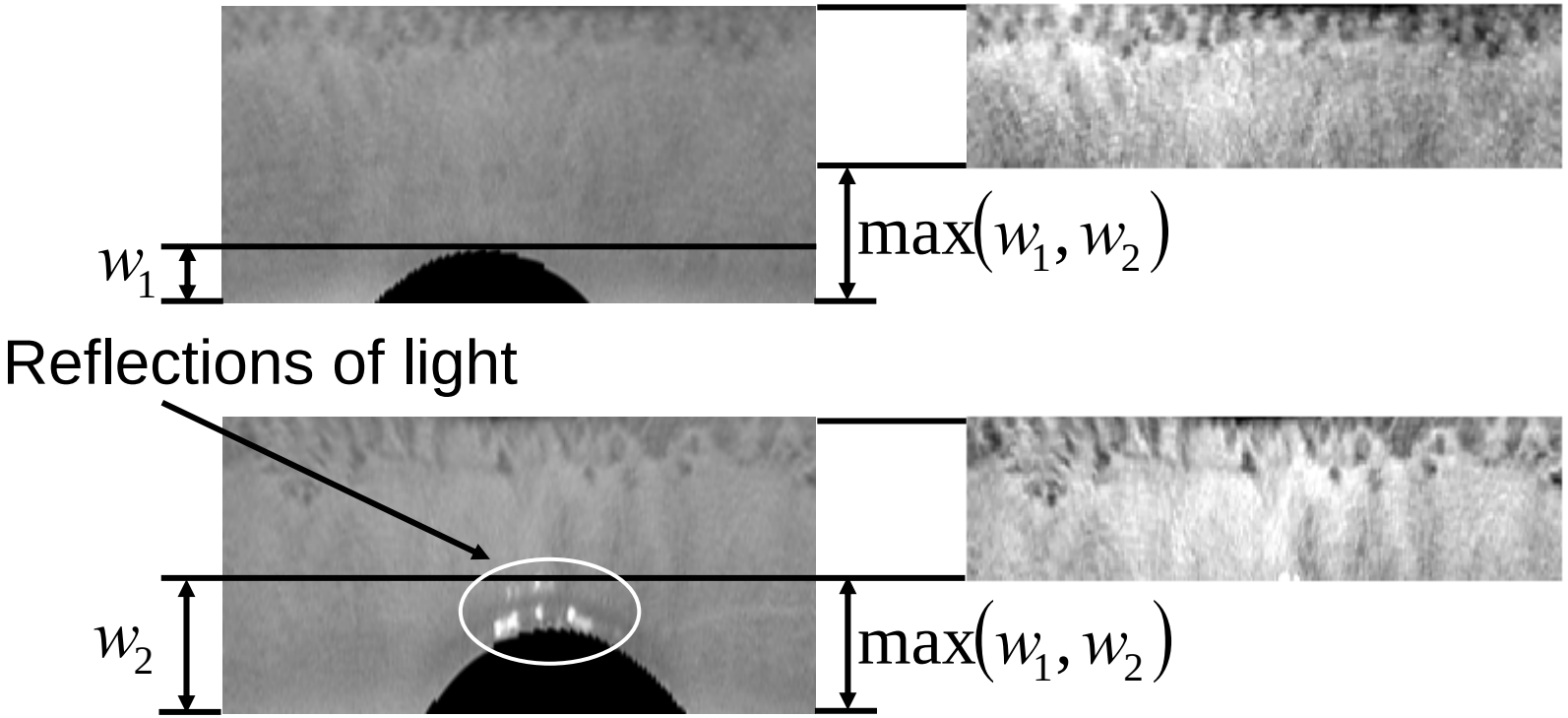


- Adaptively change the size of 2D IDFT.
- BLPOC function shows much higher discrimination capability than the original POC function.

Matching Stage

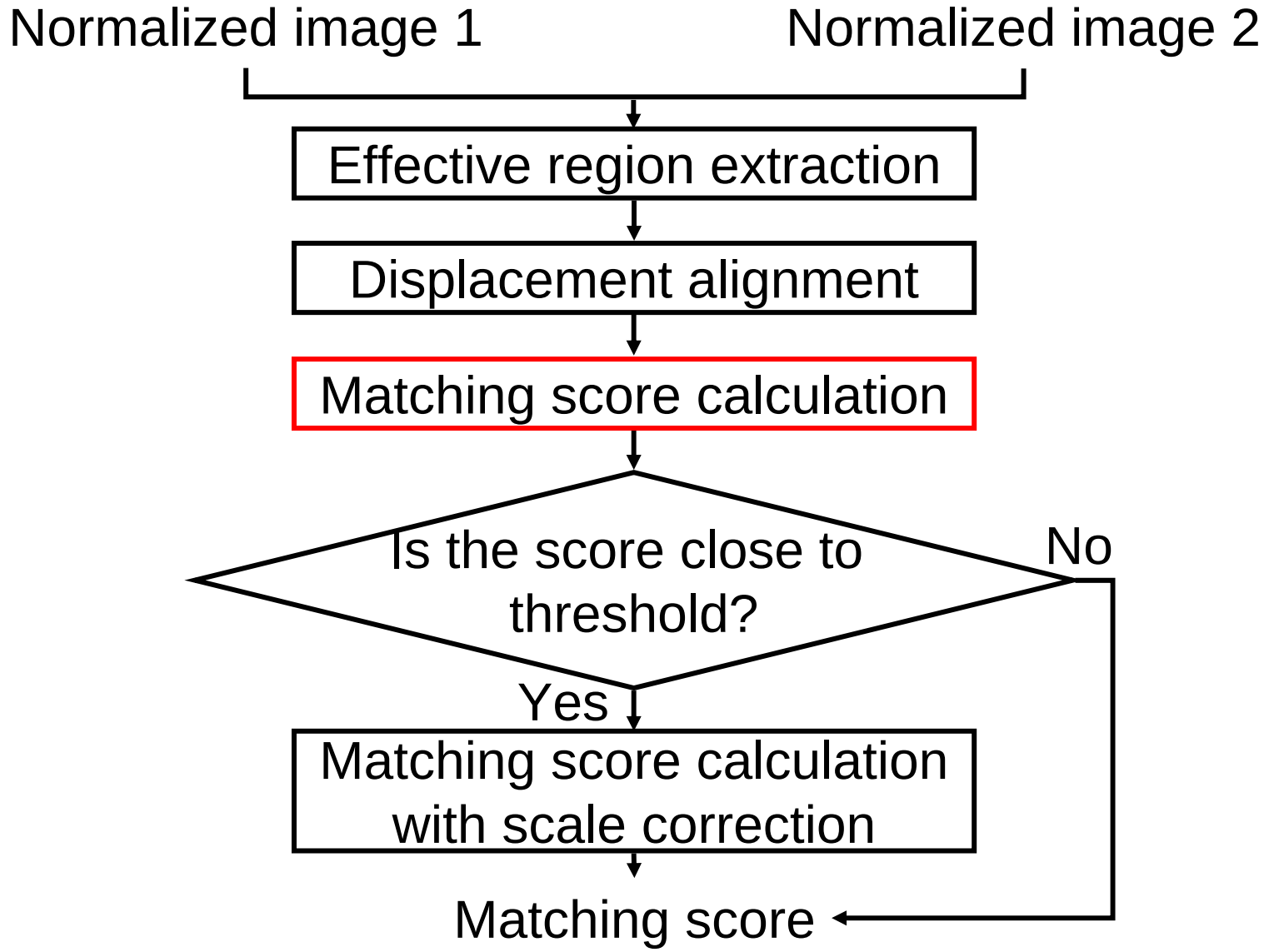


Effective Region Extraction



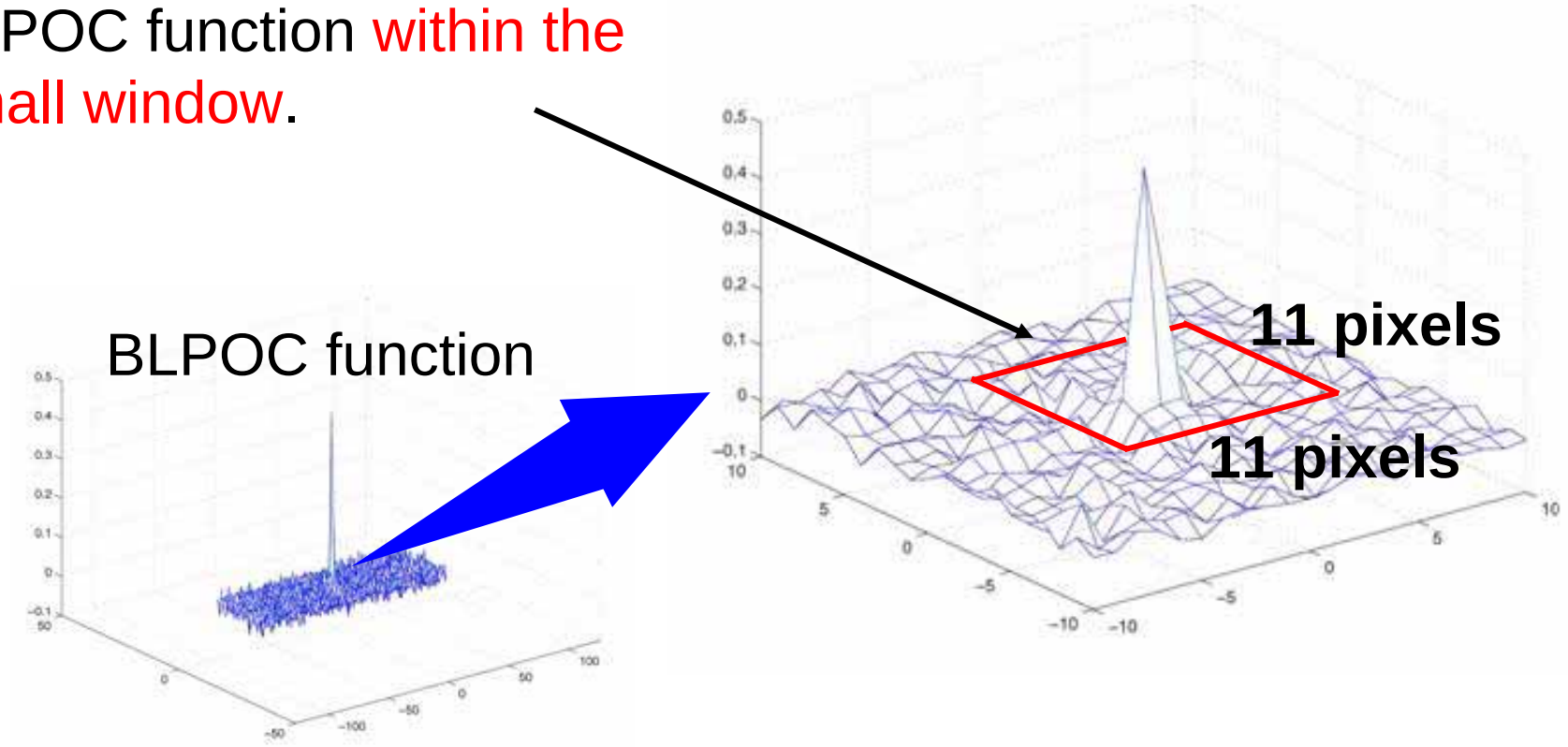
- Extract the effective regions of the same size from the two images.
- Align the displacement between the extracted images using the peak location of POC function.

Matching Stage

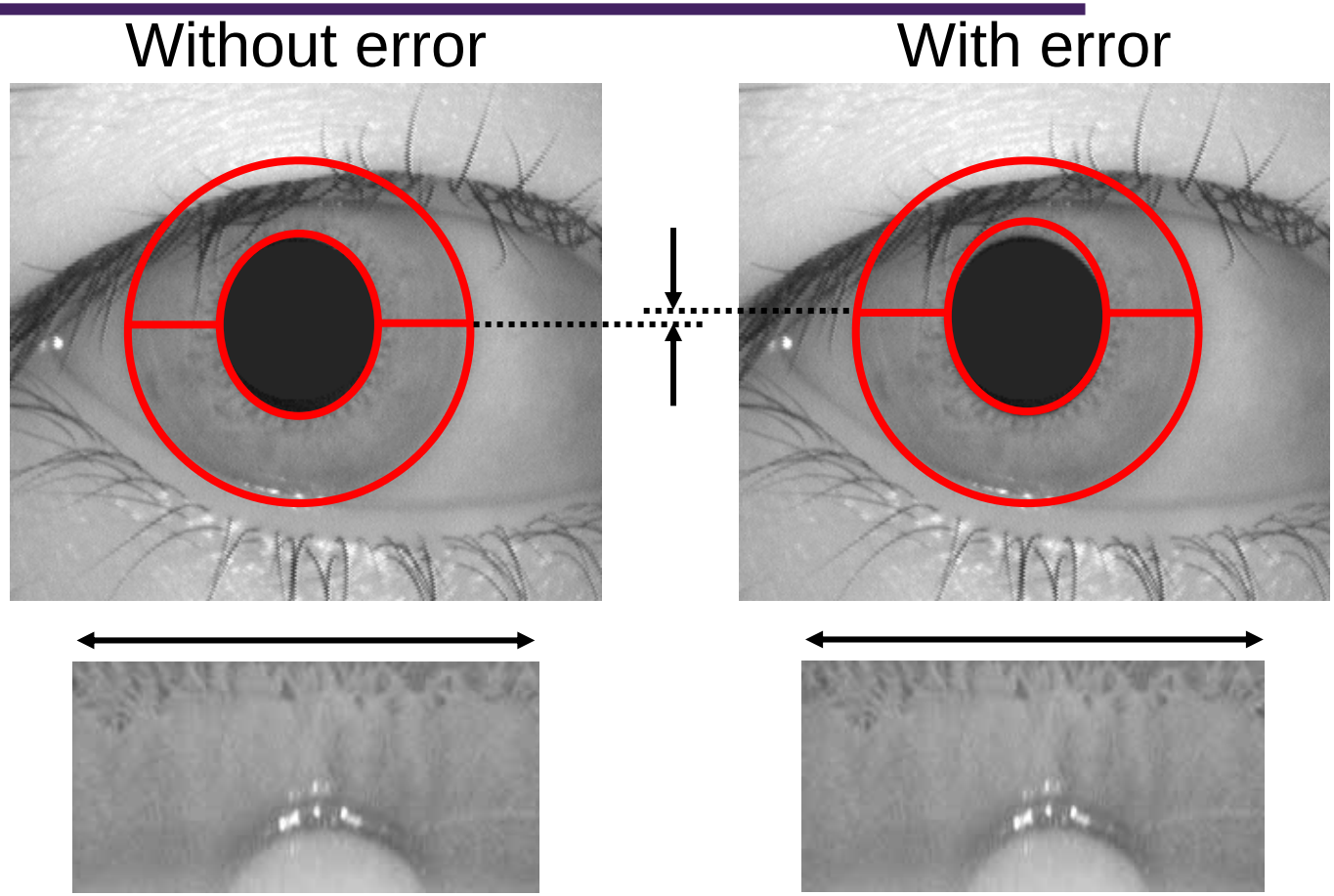


Matching Score Calculation

Calculate the matching score as the maximum value of the BLPOC function within the small window.

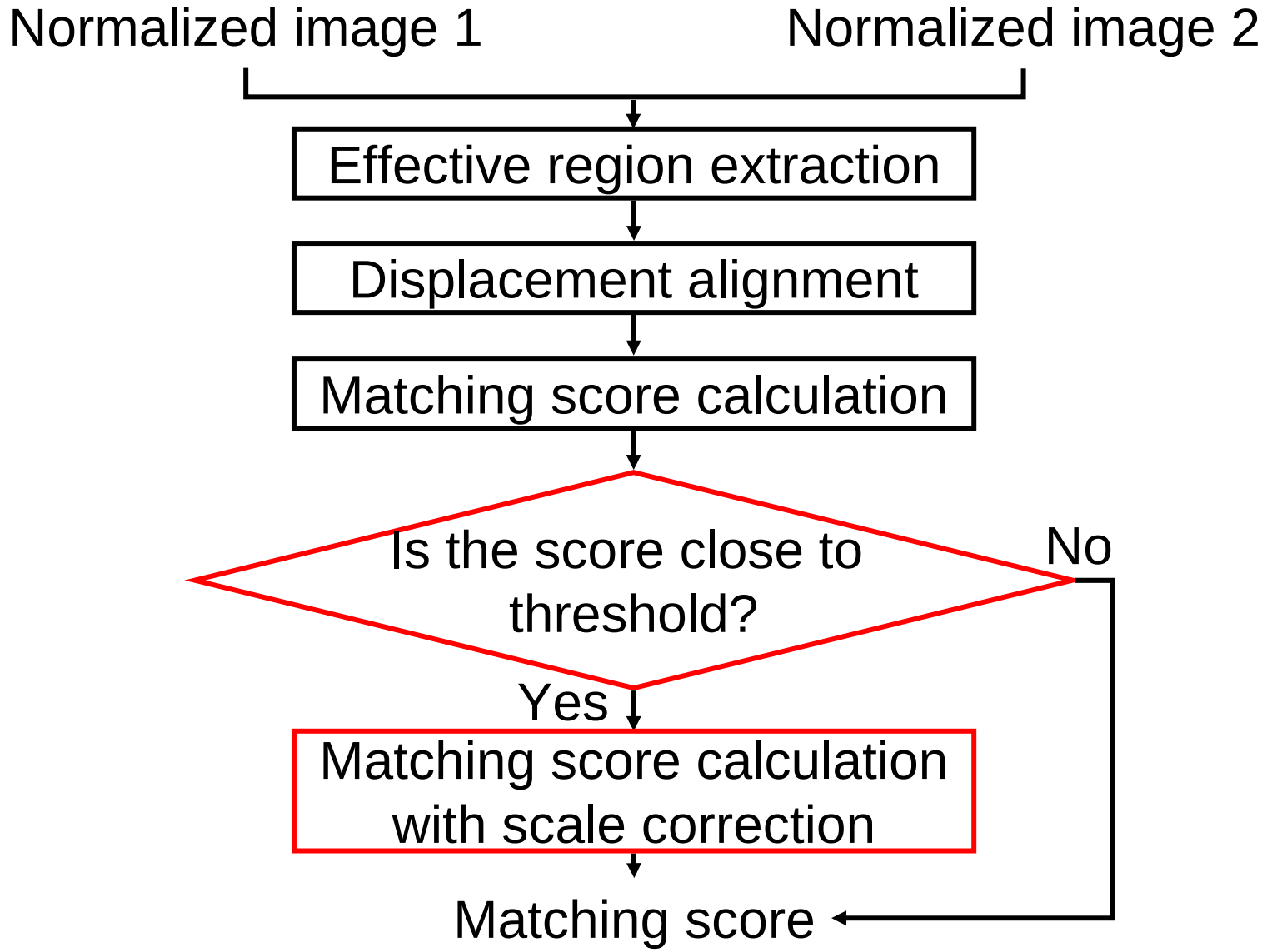


Error in Iris Localization

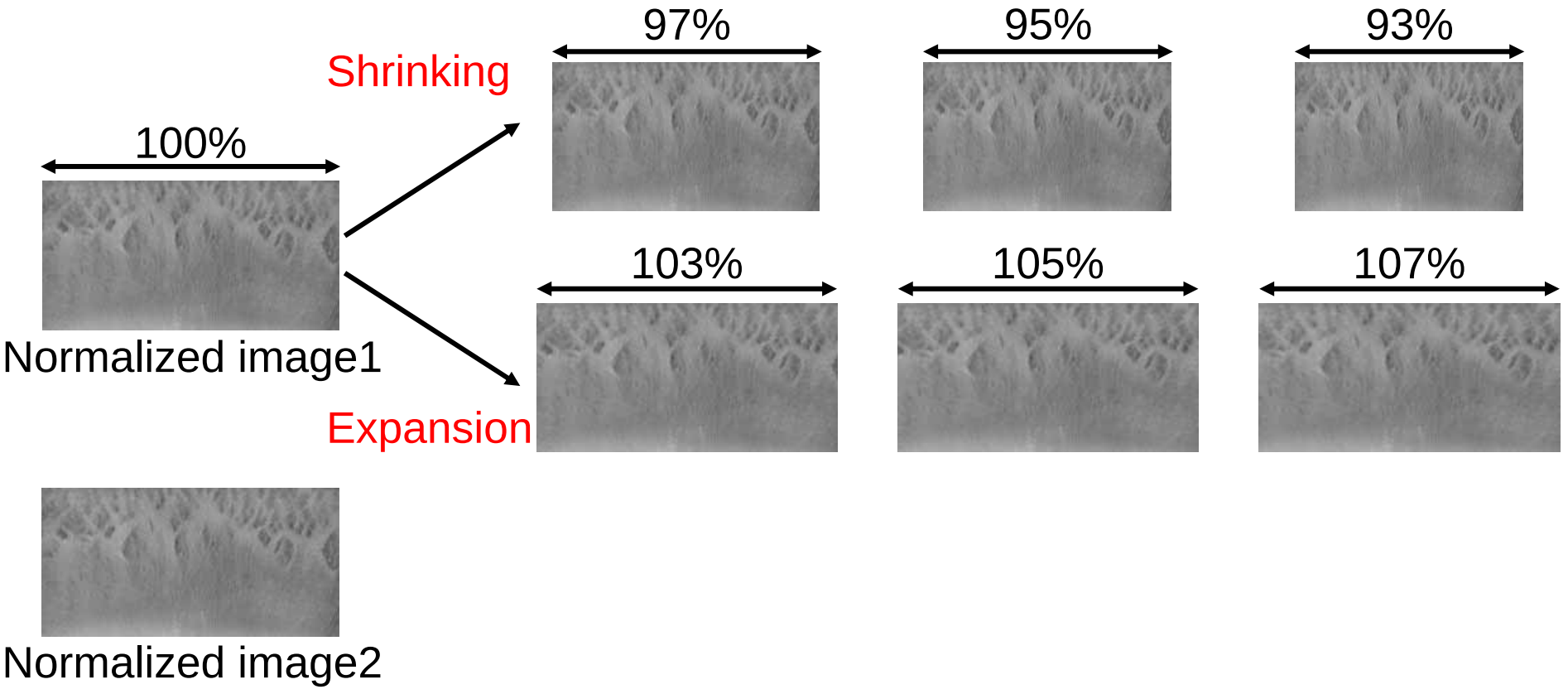


- Error in iris localization causes slight scaling in horizontal direction of the normalized iris image.
- In the case of genuine matching, this reduces the peak.

Matching Stage

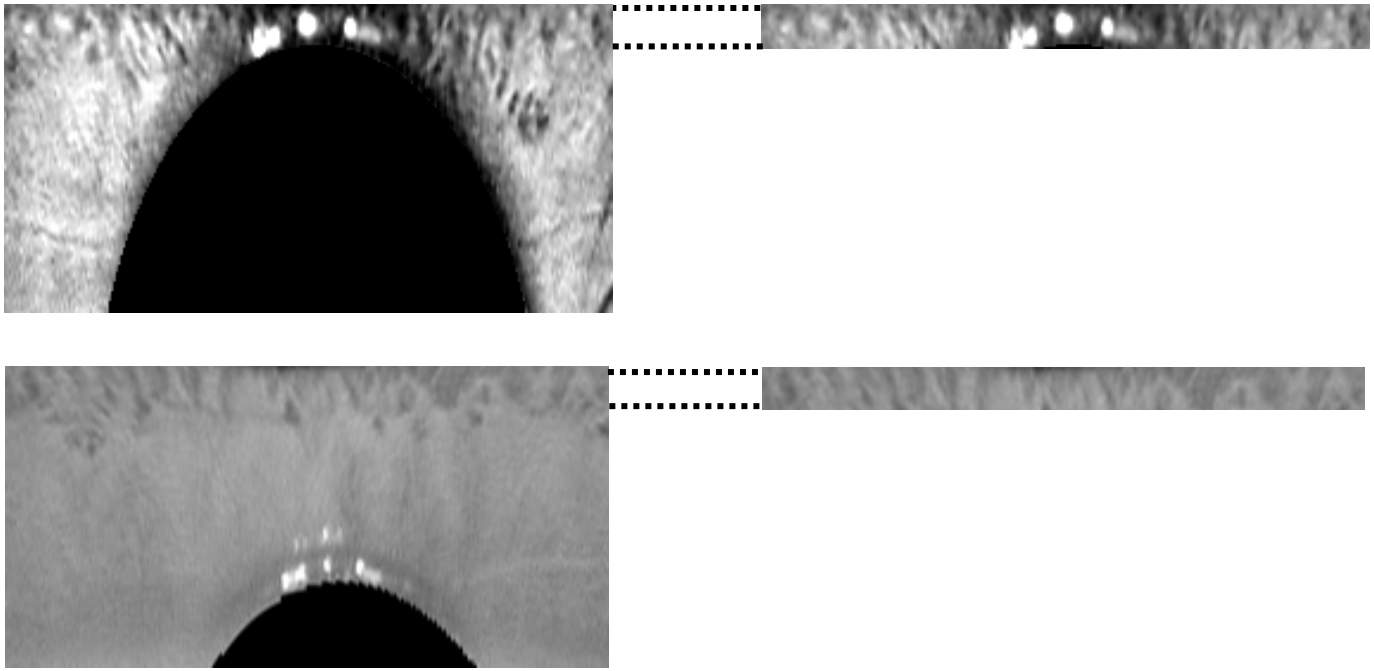


Scale Correction



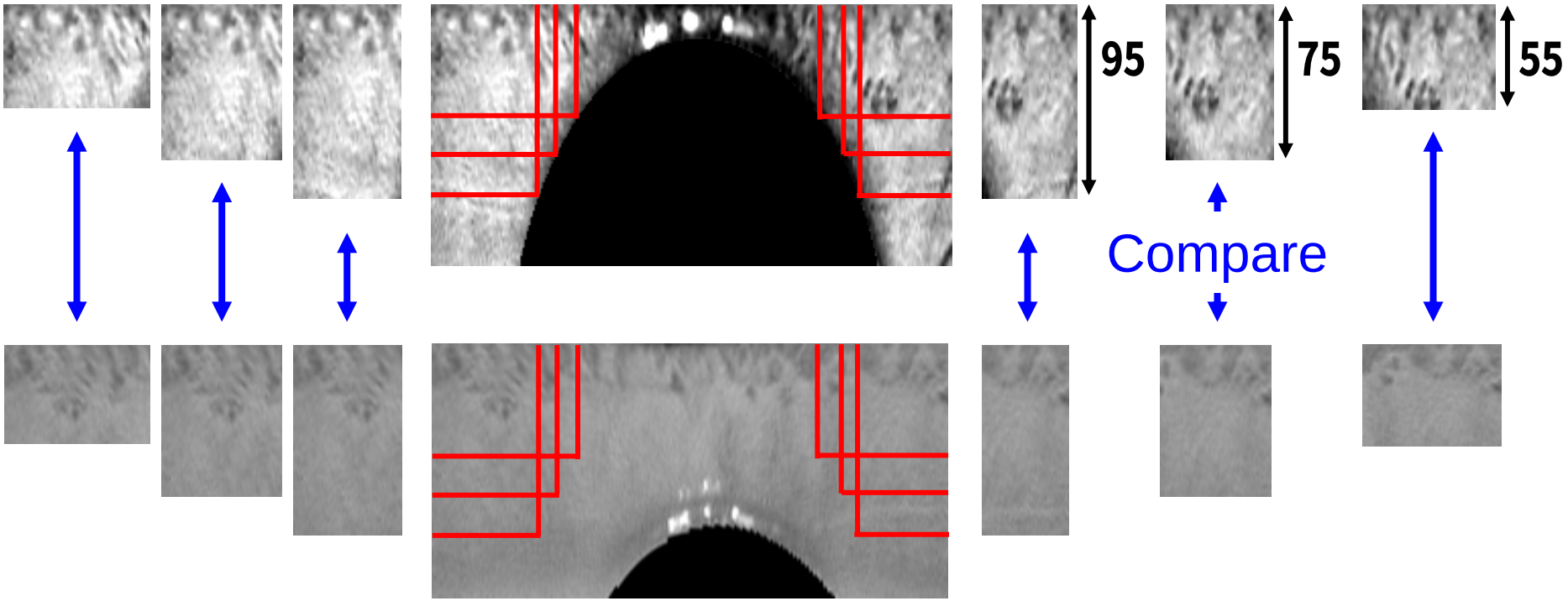
- If the matching score is close to the threshold, generate a set of scaled images and calculate matching scores for the generated images.
- Select their maximum score as the final matching score.

Possible Problem in Matching Stage



- A problem may occur when the most of the normalized iris image is covered by eyelid.
- Extracted region becomes too small to perform image matching.

Multiple Sub-Regions Extraction



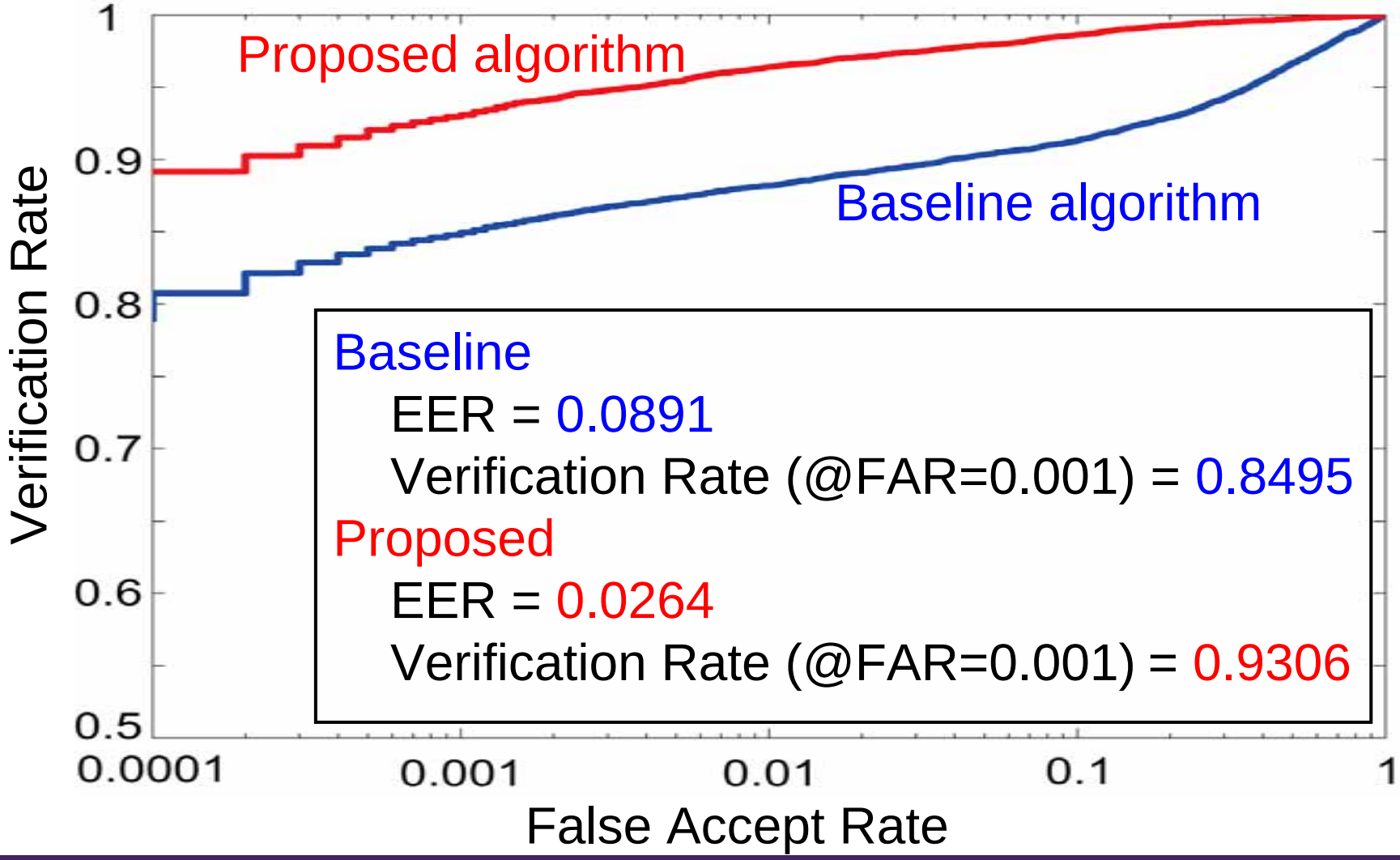
- Extract multiple effective sub-regions from each iris image by changing the width parameter.
- Matching score is calculated by taking an average of matching scores for the sub-regions.

ICE Experiment (Fully Automatic)

- Experiment 1 (irises from right eyes)
  - 1425 iris images (124 unique eyes)
  - Evaluation of the genuine matching scores
    - All the possible combinations: 12,214 attempts
  - Evaluation of the impostor matching scores
    - All the possible combinations: 1,002,386 attempts

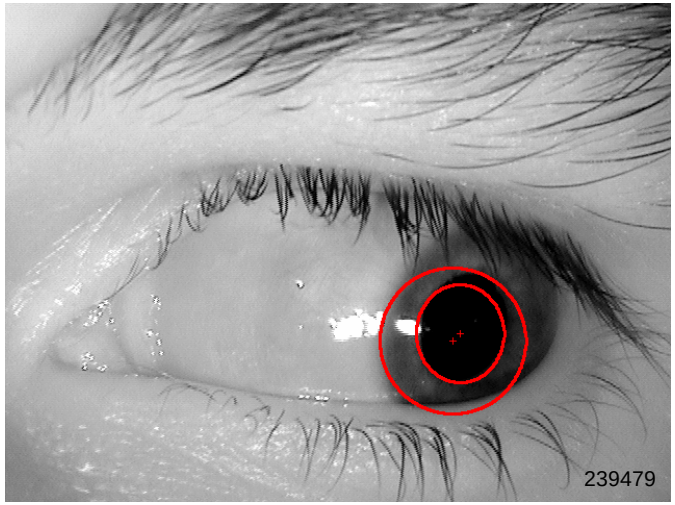
Results

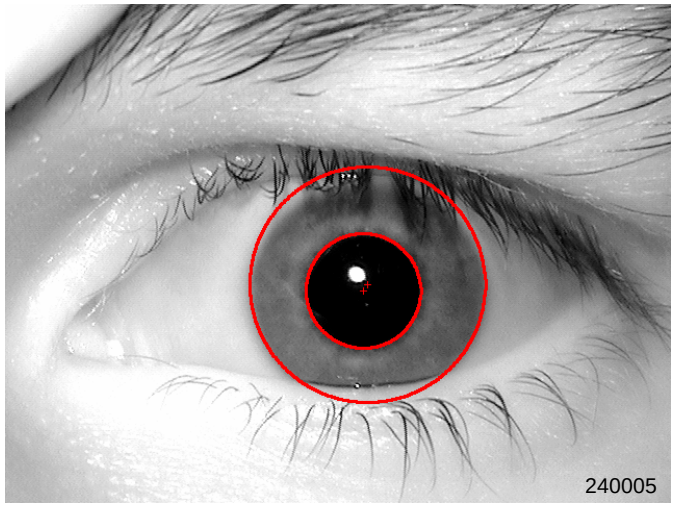
- ROC curve

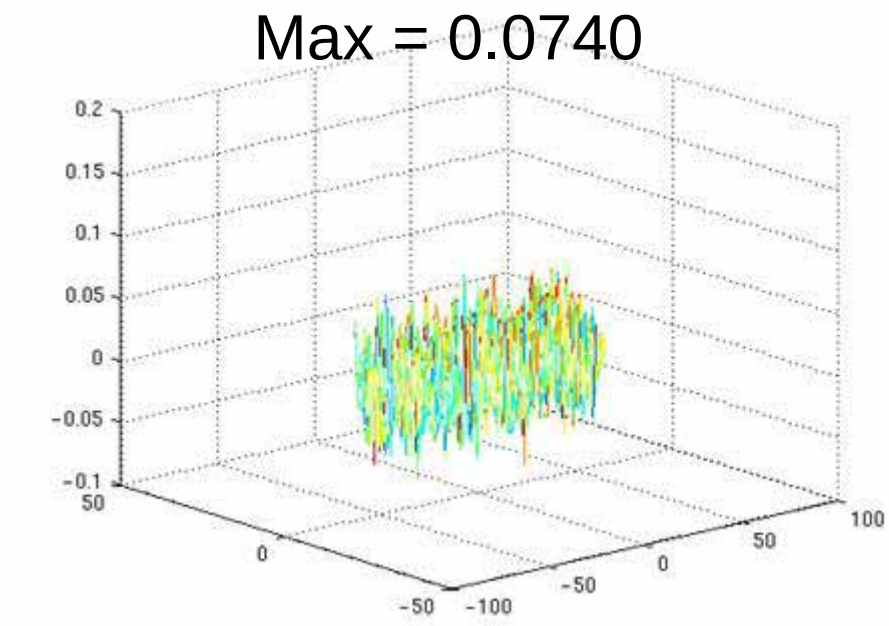


Unsuccessful Matching (genuine matching)

- Miss-localization (Non-orthogonal)

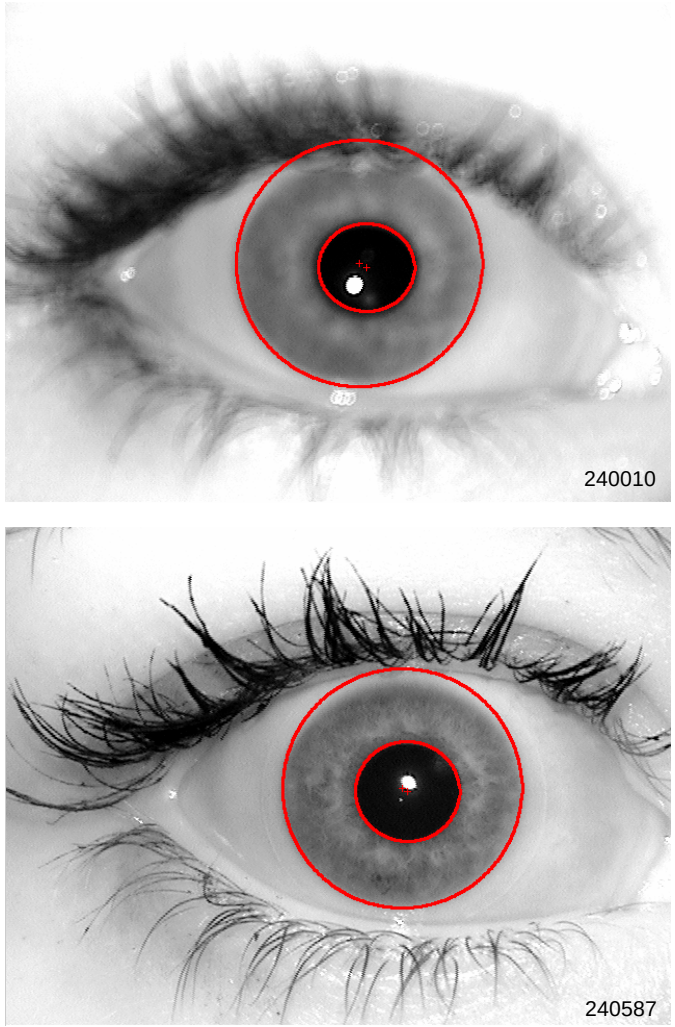


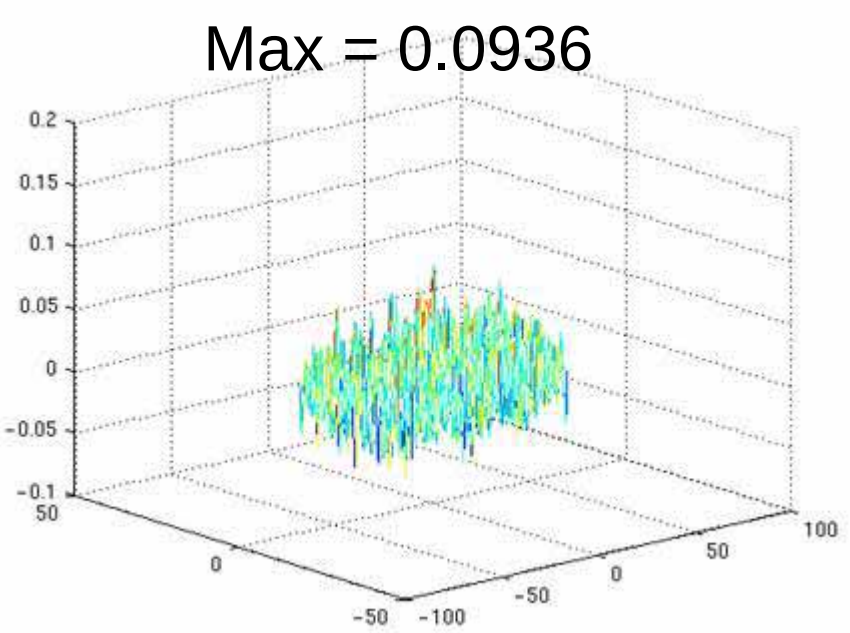




Unsuccessful Matching (genuine matching)

- Defocused





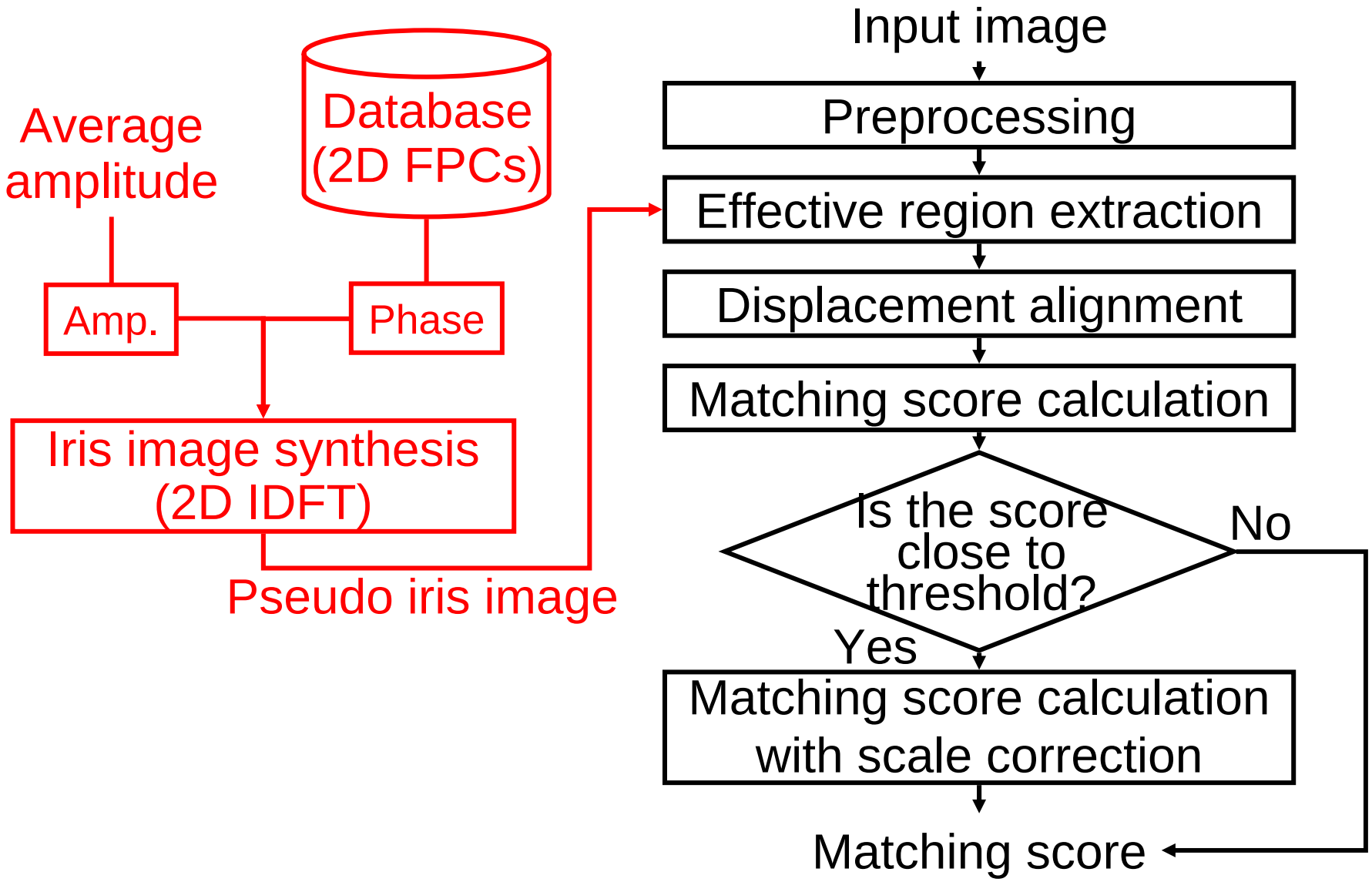
Implementation Issues

- Proposed algorithm assumes that the use of iris image directly in the system.
  - Increase in the size of iris data
  - Low security of actual iris recognition system
- Reduce the size of iris data.
- Prevent the visibility of individual iris images.

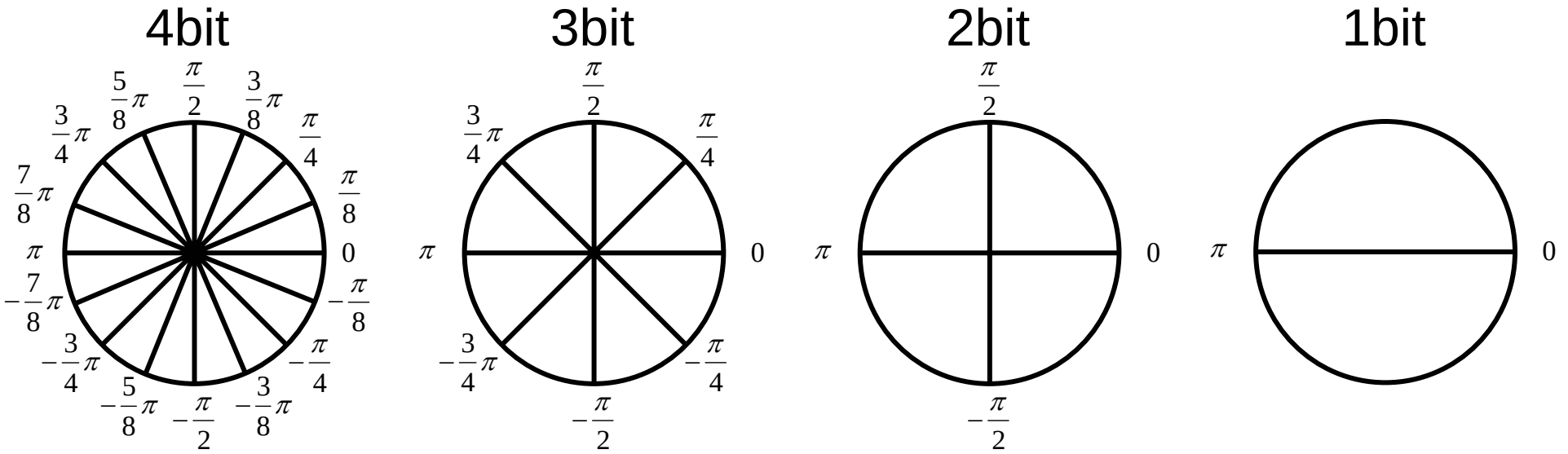
2D Fourier Phase Code (2D FPC)

➡ **Quantized phase spectrum of normalized iris image**

Iris Recognition Algorithm Using 2D FPCs



Phase Quantization and Size Reduction



- Data size of an iris image
  256 x 128 = 32 Kbyte
- Data size of 2D FPC
  - with 4-bit quantization: 8 Kbyte
  - with 3-bit quantization: 6 Kbyte
  - with 2-bit quantization: 4 Kbyte
  - with 1-bit quantization: 2 Kbyte

Conclusion

- Experimental evaluation demonstrates that the use of phase components of iris images makes possible to achieve highly accurate iris recognition with a simple matching algorithm.

Challenges for ICE 2006

- Non-orthogonal iris image matching
- Defocused iris image matching